Neutronic Parametric Study on a Conceptual Design for a Transmutation Fusion Blanket

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1. Introduction

Fusion energy may be the one of options of future energy. In all over the world, researchers are putting their efforts for its commercial and economical availability. Fusion-fission hybrid reactors have been studied for various applications in China [1]. First milestone of fusion energy is expected to be the fusion-fission hybrid reactors. In fusion-fission hybrid reactor the blanket design is of second prime importance after fusion source.

In this study conceptual design of a fusion blanket is initiated for calculation of tritium production, transmutation of minor actinides (MA) and fission products (FP) and energy multiplication calculations.

2. Methods and Results

In past blanket designs researchers used different geometries. In first step of this study the waste transmutation ratio (WTR), energy multiplication (EM) and tritium breeding ratio (TBR) are calculated for two different geometries.

2.1 Blanket Concept

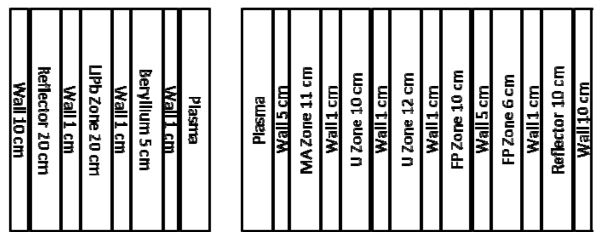
The blanket design is based on dual-cooled waste transmutation blanket [1]. The material compositions and geometrical shapes of blanket are shown in table-1 and fig-1. Two different 3-dimensional geometrical shapes were used. In first geometrical shape, outer blanket is of cylindrical shape whereas in second geometrical shape, the outer blanket is of spherical shape. The outer blanket is composed of MA zone, two uranium zones, and two FP zones. The detail layout of outer blanket is shown in figure-2b. The inner blanket consists of beryllium zone and LiPb zone. The detail layout of inner blanket is shown in fig-2a.

He gas and LiPb is used as coolant where LiPb also used for tritium production using the Li6(n,α)T and Li7(n, n)T and Pb also act as neutron multiplier [Pb(n, 2n)].

The waste transmutation efficiency is assessed by waste transmutation ratio (WTR). It is the total (n, fis) reaction rate per fusion neutron for minor actinides (MA) and total removal reaction rate of all fission products (FP) per fusion neutron [2]. Energy multiplication is the ratio of fission energy produced to the fusion neutron energy. Tritium production is assessed by tritium breeding ratio TBR.

a) b)

Figure 1: a) Blanket shape with cylindrical outer blanket. b) Blanket shape with spherical outer blanket.



a) b)

Figure 2: The detail layout of inner (a) and outer (b) blanket.

Table 1: Blanket material compositions

MA Zone	**Vol Frac %**	**FP Zone**	**Vol Frac %**	**UO2 zone**	**Vol Frac %**	**Ref Zone**	**Vol Frac %**
MA	1.5%	Cs137	1.68%	UO2	9.5%	C	90%
Pu	3.9%	I129	0.28%	LiPb	85.5%	He	10%
LiPb	89.6%	Tc99	0.23%	SiC	2.5%		
SiC	2.5%	SiC	2.5%	C	80%	**Be Zone**	**Vol Frac %**
C	2.5%	C	80%			Be	60%
		He-gas	16.5%			He	40%

2.2 Neutronics Calculation

The calculations of WTR, EM and TBR have been done using MCNPX [3]. The results for the two geometries are shown in table-2. The results for two blanket geometries are almost same since the variance of results of two geometries is very small.

Table 2: Waste transmutation ratio for MA and FP zones energy multiplication for MA and U zone and tritium breeding ratio of the two blanket geometries.

	FP Zone	MA Zone	MA+U Zone	Total
Geometry	WTR	WTR	EM	TBR
Cylinder outer blanket	0.040	0.053	11.341	1.007
Sphere outer blanket	0.043	0.052	11.023	1.002
Variance	2.3E-6	1.8E-7	2.5E-2	8.03E-6

2.3 Neutron Energy effect on neutronics parameters

The effect of incident neutron energy on TBR and WTR calculations is also investigated for the MA-zone, U-zone, LiPb-zone and FP-zone separately. A simple cubical geometry is used to study the effect of neutron energy on TBR and WTR for MA and FP. The calculated values of TBR are shown in figure-3 and WTR values are shown in fig-4. The total fission cross section of MA (Am241, Am243, Np237 & Cm244), tritium production cross section for Li6 & Li7 and absorption cross section of FP (I129, Tc99 & Cs137) were obtained from KAERI web database of nuclides [4], the plots of these cross sections are shown in figure-5. Cross section plots were used to check the reliability of the calculation procedure of TBR and WTR. The trend of calculated TBR and tritium production cross section resembles. TBR is higher at low energy as cross section of Li6 is higher and a peak of TBR appears at about 200 keV as a peak appears in Li6 cross section at the same energy. After 4 MeV the tritium production cross section of Li7 suddenly start increasing which result in a sudden increase in TBR. WTR for FP decrease with neutron energy as the absorption cross section decrease with energy. WTR for MA increased quickly between 0.1-1 MeV as the total fission cross section increase quickly between 0.1-1 MeV. Beyond 1 MeV the cross section is almost constant but a quicker increase in WTR is observed beyond 5 MeV. It may be because of an increase in ν (average number of neutrons released per fission) value of minor actinides.

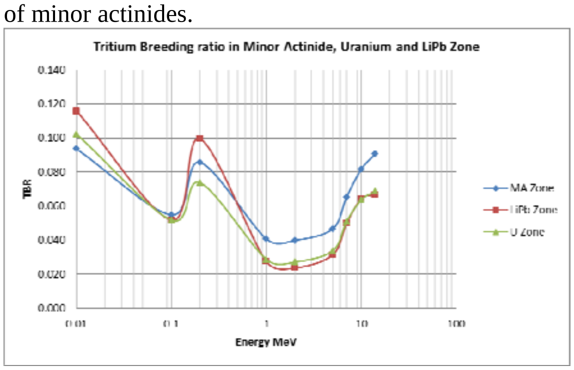


Figure 3: The trend of TBR calculated in MA zone, U zone and LiPb zone with incident neutron energy.

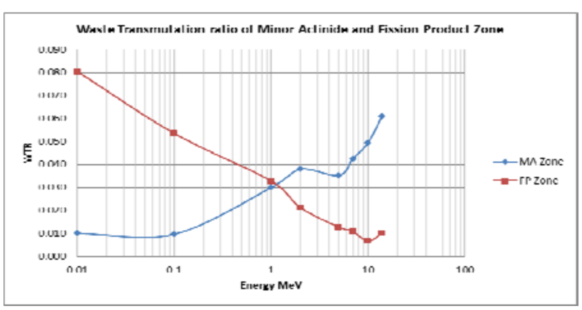


Figure 4: The trend of WTR of MA zone and FP zone with incident neutron energy.

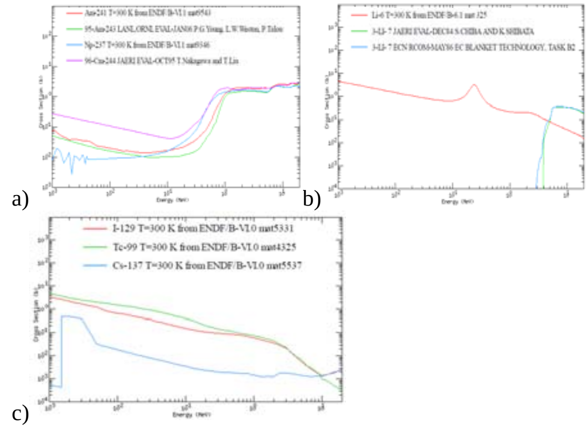


Figure 5: a) total fission cross section of MA b) tritium production cross section of Li6 & Li7 c) absorption cross section of FP [4].

3. Conclusions

The effect of geometry on neutronics parameters calculation for a blanket design study is negligible. The calculation procedure for TBR and WTR was reliable. Since MCNPX do not facilitate the time based calculation including the depletion, this procedure could only provide a rough idea about the neutronics parameters of blanket design. MONTEBURN or CINDER90 is a better approach for the calculation of neutronics parameters. In future work these parameters will be calculated with MONTEBURN. This study was an initial step for a conceptual design of fusion blanket.

REFERENCES

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